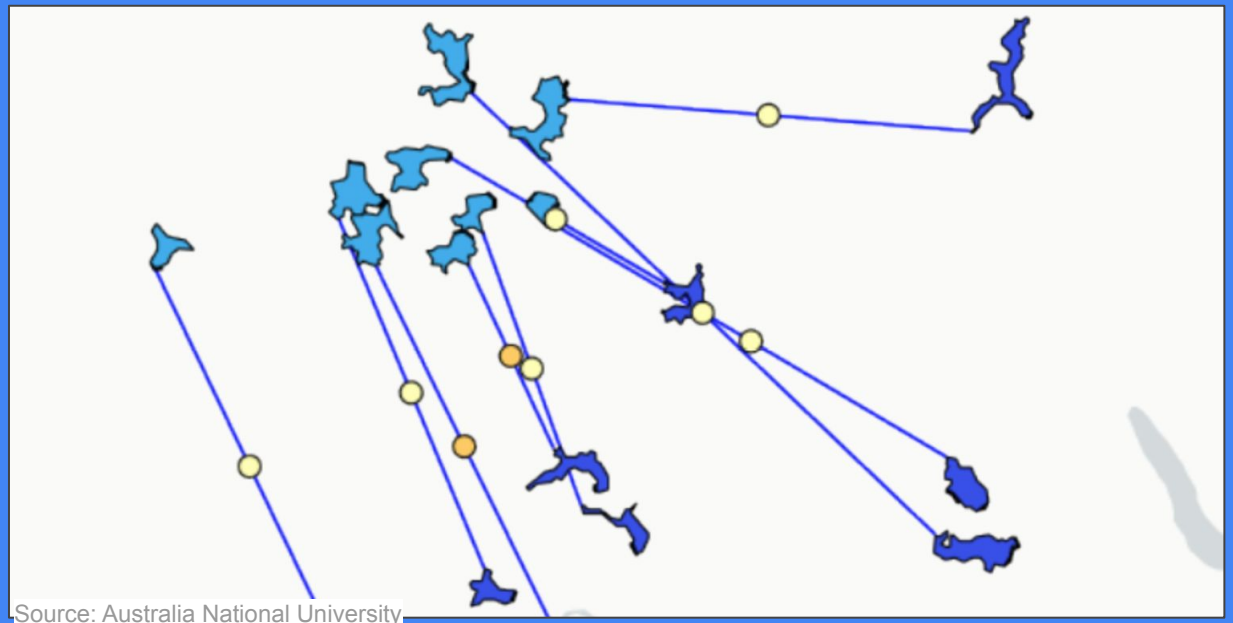
Assignment of Reservoirs for Pumped Hydro Storage Systems



Source: Australia National University

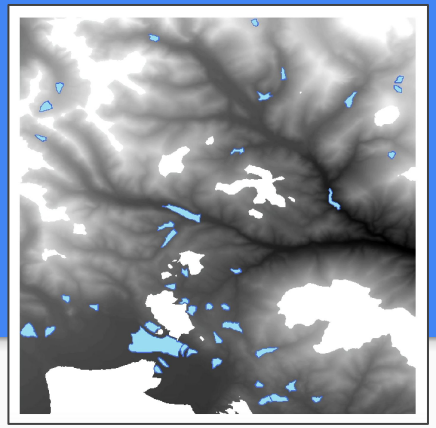
Quinsen Joel
Network Flows
Spring 2020

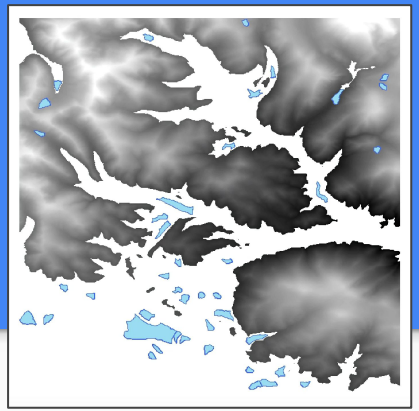
Context/Motivation

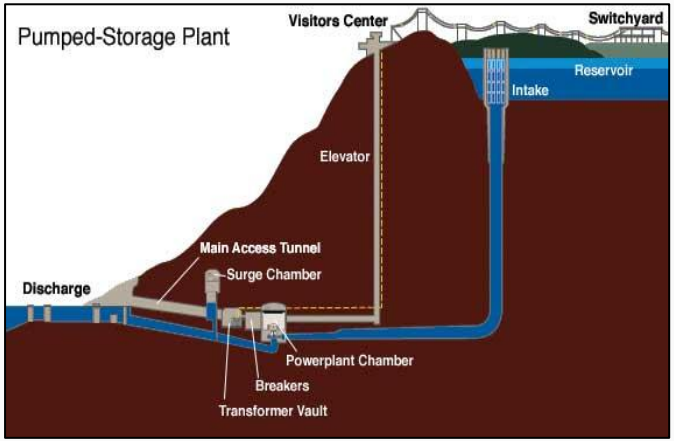
Pumped Hydro Storage is making a comeback.

Requires: enough vertical elevation difference to generate sufficient power, but as little horizontal distance as possible to minimize construction costs.

This project piggybacks off of the outputs of modeling by Bin Lu et. al.







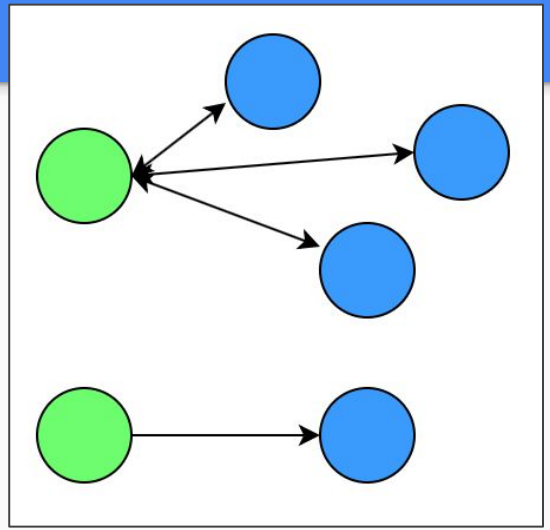
Potential Formulations

Matchings vs. Other Subgraphs

Searching for arbitrarily large connections of reservoirs would be very complex.

Configurations with exactly one upper and one lower reservoir are most popular.

Matching problems are well-known and offer standard algorithmic approaches for solving.



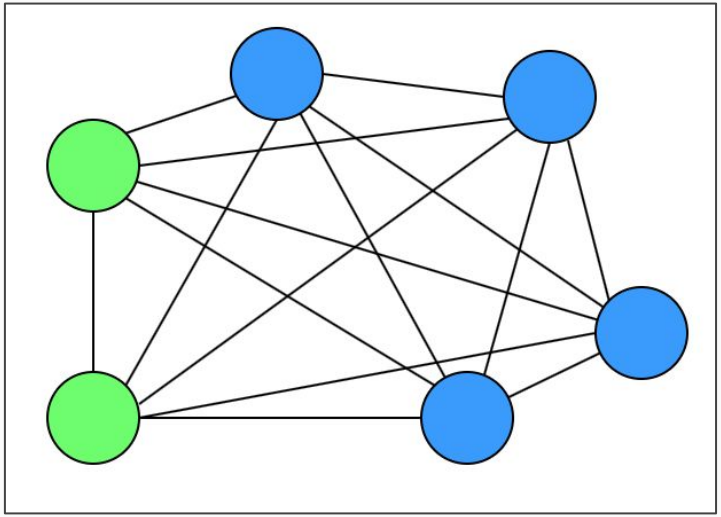
Potential Formulations

Optimal vs. All Matchings

Discover all potential matchings between reservoirs?

Optimization of these matches could allow for a more useful and succinct summary of the potential for hydropower

Optimization will undoubtedly be necessary to increase the chances of successful deployment



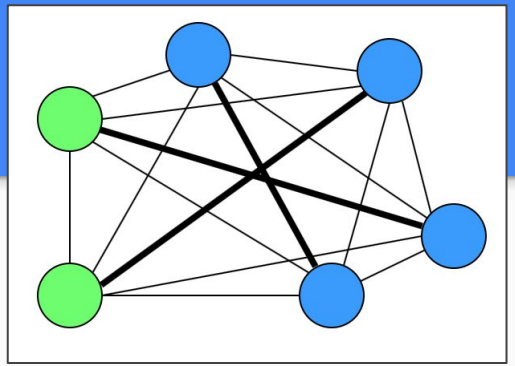
Potential Formulations

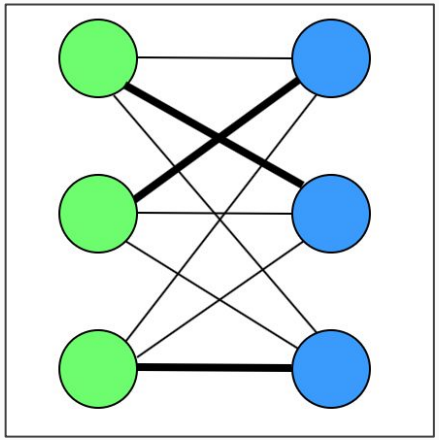
Bipartite vs. General Matching

Maximum horizontal distance threshold to be considered.

Maximum horizontal distance threshold gives a bipartite network.

General Matching usually much harder than Bipartite Matching anyway.





Potential Formulations

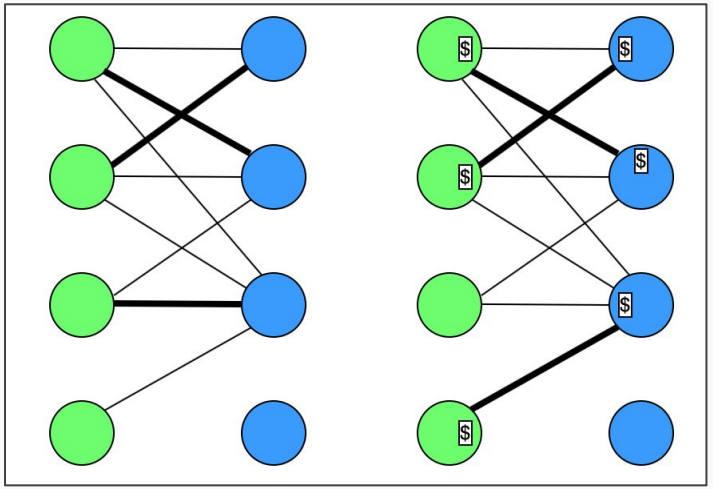
Weighted Bipartite Matching vs. Maximum Bipartite Matching

Is quantity or quality more important for PHS discovery?

Weighted Bipartite problem is harder because it considers costs as well as capacities.

Cost metric will be:

VH/WD: V: Volume, H: Head, W: Water-Rock Ratio, D: Distance.



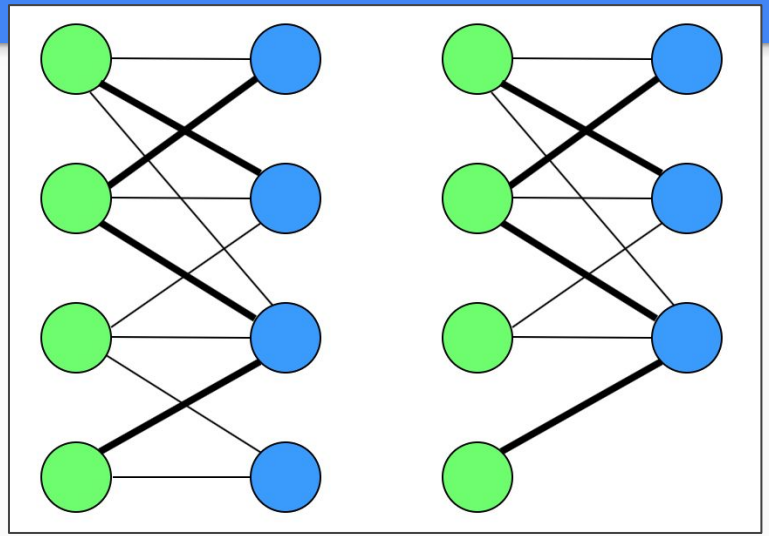
Potential Formulations

Balanced vs. Unbalanced Assignment

Balanced matching is more well known.

Most likely bipartite graph will be unbalanced.

Transformations from unbalanced to balanced possible.



Assignment Representation

Network Setup

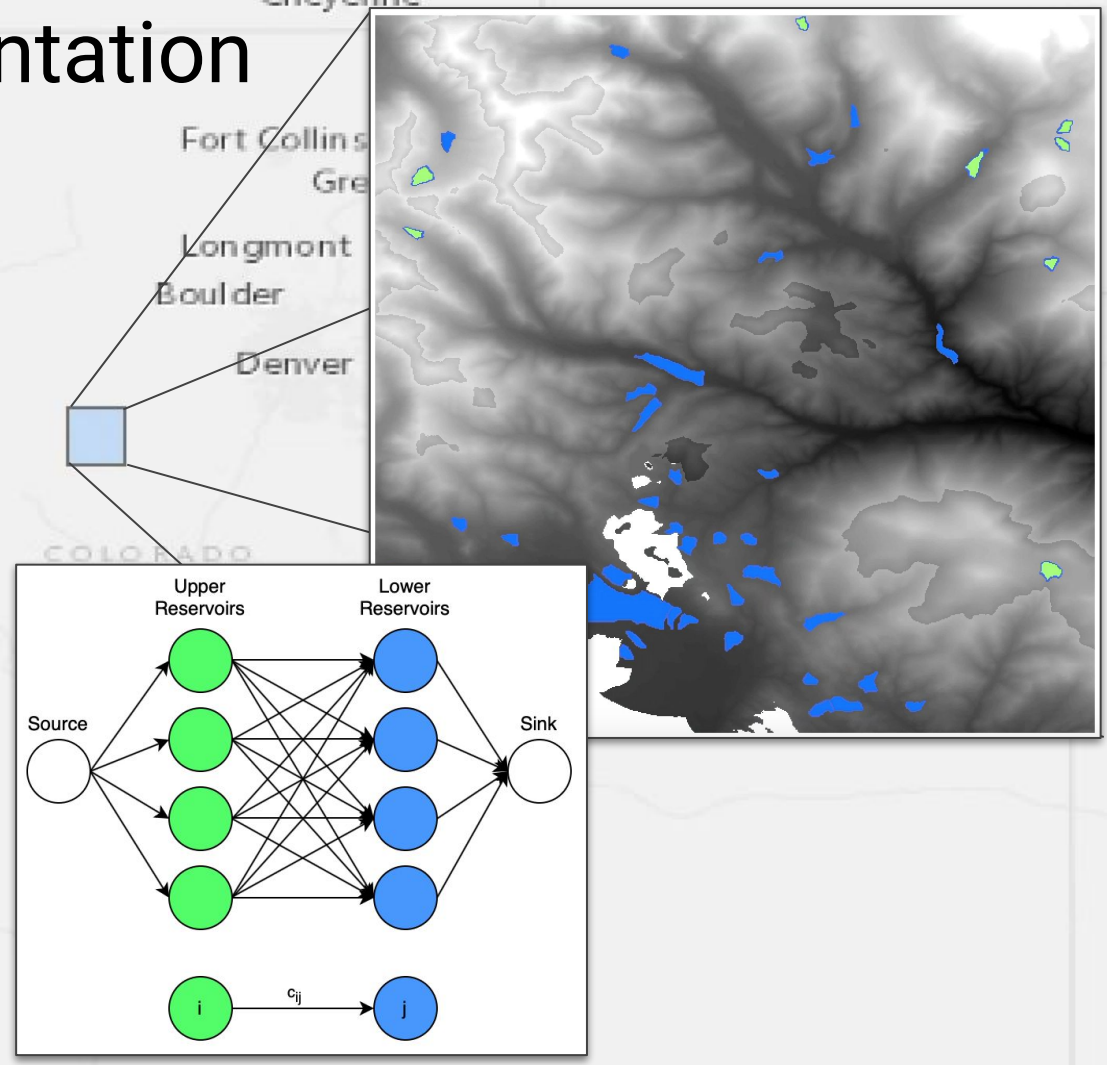
Bipartite Network.

Balanced sets of nodes.

Weight metric added as costs of arcs. On source and sink arcs, cost is 1.

All arcs uncapacitated.

Source and Sink added to initialize algorithm.



Assignment Representation

Solution Methods

Straight-forward:

Successive Shortest paths

$O(n_1 S(n, m, C))$

Hungarian Algorithm

$O(n_1 S(n, m, C))$

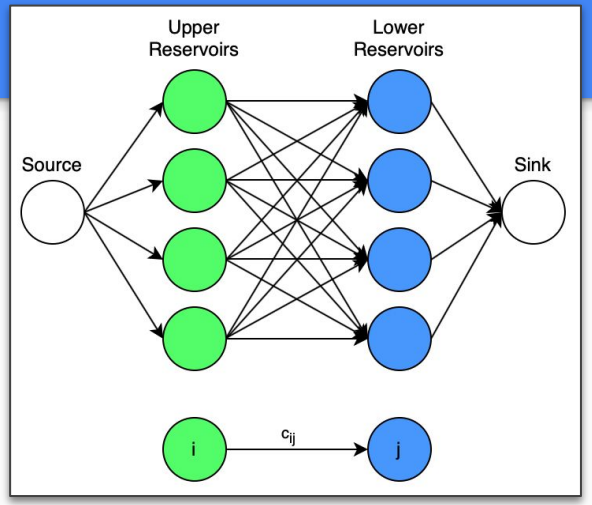
More Advanced:

Network Simplex

$O(\sqrt{n_1}\, m \log(nC))$

Cost Scaling

$O(VE \log V \log(VC))$



Conclusion

An automated framework for finding PHS sites given the actual outputs of a previous researcher's model is possible.

Once each of the two parts of the process (reservoir finding & reservoir matching) are analyzed for their theoretical and empirical complexities, researchers will have a powerful tool for assessing this technology's potential for utility-scale power.

References

1. https://nationalmap.gov.au/renewables/
2. Bin Lu, Matthew Stocks, Andrew Blakers, Kirsten Anderson. Geographic information system algorithms to locate prospective sites for pumped hydro energy storage. 2018.
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4. Zvi Galil. Efficient Algorithms for Finding Maximum Matchings in Graphs. 1986.
5. Lyle Ramshaw, Robert E. Tarjan. On Minimum-Cost Assignments in Unbalanced Bipartite Graphs. 2012.